PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION.

Improvements in Reciprocating Pumps.

We, G. & J. Weir Limited, of Holm Foundry, Cathcart, Glasgow, a British Company, Harold Hillier, of the same address, a British Subject, James Colquhoun Macfarlane and William Allan Macfarlane, Directors of the Macfarlane Engineering Company, Limited, of Netherlee Road, Cathcart, Glasgow, both British Subjects, do hereby declare the nature of this invention to be as follows:—

In the prior specifications 335,932, 336,810 and 337,205 there are described methods of obtaining a variable output from a displacement pump driven by a constant speed means and consisting of one or more units, each unit comprising two displacers of equal displacement capacity driven by separate crank shafts and working in a common chamber so as to vary the volumetric capacity of the chamber, variation of the total volumetric displacement during one revolution being obtained by altering the relative phase of the shafts.

For altering the relative phase of the two crank shafts, according to the arrangement described in specification 335,932, there are provided two synchronous A.C. motors, one for each crank shaft, and the angular phase displacement is obtained by revolving the stator of one synchronous motor by means of a pony motor or other device, thereby altering the position of the poles of the second stator relatively to those of the first.

Our present invention may be regarded as an improvement on that described in specification 335,932, in respect that in lieu of synchronous motors for the purpose of driving the two shafts at a common speed we may use A.C. induction motors of either the slip ring or squirrel cage types, or where a D.C. supply is available we may use D.C. motors.

The method of control adopted is differentiated from that described in specification 335,932 in that, instead of using synchronous motors and altering the relative angular position of the poles, we use induction motors of D.C. motors and alter the slip in the case of A.C. machines, or produce a slip in the case of D.C. machines.

In practice we may exercise a choice of several methods of altering the slip or producing relative slip as described below, but in all cases we cause the variation to take place by the operation of a hunting controller controlled by the pressure or volume of fluid discharged.

For altering the relative slip of induction motors where these are used we may mount one or both stators in such manner that they may be revolved by means of a pony motor, say in the manner described in specification 335,932, but in this case, instead of serving to alter the angular position of the poles of one motor, the pony motor serves to increase or reduce the slip speed of one motor relatively to the other. Where both stators are acted on, the movements of the stators under the control of the pony motor are such that the slip of one motor is increased while that of the other is reduced and vice versa.

Squirrel cage or slip ring motors may be employed, the control of the pony motor being obtained from the hunting controller.

Alternatively, we may use slip ring induction motors and use the hunting controller to insert or cut out resistance in the rotor circuit of one or both machines.

A squirrel cage motor with a relatively high resistance rotor may be used in conjunction with a slip ring motor in which resistance is inserted or removed from the rotor circuit, thus increasing or reducing its slip relatively to that of the squirrel cage machine.

According to a preferred embodiment we use two induction motors, preferably of the squirrel cage type, and couple to each motor a D.C. generator of a size sufficient to control the slip within the desired limits. The D.C. generators may be driven by belt, chain, or gear but are preferably coupled direct to the A.C. machines. These D.C. generators have their armature circuits coupled in opposition, so that with equal fields the voltage generated is the same in each and no current passes. If, however, the hunt-

ing controller operates to insert resistance in one field and remove it from the other, one D.C. machine becomes a motor and the other D.C. machine a generator, thus transferring power from one A.C. motor shaft to the other.

The effect is to increase the slip on the A.C. machine that is coupled to the generating D.C. machine and to reduce the slip on the A.C. machine that is coupled to the motoring D.C. machine, thereby obtaining the effect desired.

Where a D.C. supply is available the two main motors may be D.C. machines, and in this case the hunting controller can operate directly to insert resistance in the field circuit of one machine and remove it from the field circuit of the other and vice versa.

The hunting controller consists, generally, of two parts, one part operated upon by the pressure (or volume) of the discharged fluid, and the other part operated on by the angular phase displacement of the two crank shafts, in such manner that when, for instance, a rise in pressure (say) of the discharged fluid takes place, the movement of the first part will cause a phase change to take place in the angular positions of the two crank shafts so as to reduce the volumetric displacement of the displacers, but immediately this phase displacement is achieved the movement of the second part of the hunting controller will cause this second part to meet up on the first part, with the result that the phase displacement motion is stopped until the first part again moves under the control of the fluid pressure (or volume).

One type of hunting controller applicable to the second and third above described methods of changing the slip of an induction motor and applicable also to the control of D.C. machines is as follows:—

The second part of the hunting controller consists of a sun and planet gear driven by the two crank shafts.

The two sun wheels are each connected by suitable gearing to one of the crank shafts and arranged so that they revolve in opposite directions. The planet wheel revolves idly and the casing in which it is mounted remains stationary so long as the speeds of the sun wheels are equal. Should a relative change of speed take place, however, in the two crank shafts, the casing carrying the plane wheel will revolve and the movement of this casing is caused to control the movement of a potentiometer coupled resistance, either by revolving the frame carrying the contacts of the resistance, or by moving longitudinally by means of a cam, or in any other suitable manner.

The first part of the hunting controller consists of a contact, adapted to work on the contact studs of the moving potentiometer. The position of this contact may be controlled by a pressure regulator of any well known type operated by the discharged fluid, or by a float or by other means, the operation being such that the contact is normally at the central or zero position on the potentiometer, the speeds of the two motors being then equal.

Should a change of pressure (or volume) take place, the contact is moved away from the zero position in such direction as to cause the appropriate change to take place in the motor speeds. Immediately, however, this change of speed does take place, the second part of the hunting controller moves the potentiometer contact studs in such direction as to overtake the pressure (or volume) controlled contact, thereby establishing the zero position of the potentiometer resistance under the pressure (or volume) controlled contact and stopping further relative movement.

In adopting the first above described method of obtaining slip variation where a pony motor is used the second part of the hunting controller may be used to vary the position of two sets of contacts, one for forward and the other for reverse rotation, while the pressure (or volume) controlled contact moves between these sets of contacts to start the pony motor in the required direction, stoppage of the change being effected after the second part of the hunting controller has moved sufficiently far to break contact again. Resilient contact parts may be used, and any of the well known methods of reducing or eliminating sparking at the contacts may be adopted.

Alternatively, where the first above described method of altering the slip is adopted, we may use a D.C. pony motor and supply its armature from a small D.C. generator driven by one of the main motors. The field of this auxiliary generator as well as the field of the pony motor may be supplied by a second small D.C. generator also driven by one of the main motors.

The control of the pony motor can then be effected by means of the hunting controller operating on the field of the first small D.C. generator, to vary or reverse its voltage. In this way smooth control of the pony motor without the necessity for making or breaking electrical contacts can be obtained.

Any other known methods of operating the gear mechanically or electrically may be used. For instance, instead of the second part of the hunting controller being of the sun and planet gear type,

operating directly off the crank shafts, we may make use of the electrical currents set up in the circuit of the auxiliary machines, as mentioned with reference to the third described method of slip control, to operate a motor, solenoid, or similar device for the purpose of returning the potentiometer to zero after the action of the first part of the hunting controller. In this case it will be necessary to ensure that the time of operation of the second part of the hunting controller is equal to the time required to change the crank phase angle by the required amount, and, to ensure this, we may adopt means such as a regulator in the field of the motor controlling the motion of the potentiometer resistance.

The essential condition in the hunting control is that any displacement of the first part of the hunting controller, under the action of a change of pressure (or volume), from the zero or equal speed condition, is followed by a change of relative phase of the two crank shafts, which change, however, acting through the second part of the hunting controller, causes the second part to follow up the first part, whereby, when the necessary change of phase relationship has taken place, the controller is restored to zero position and thereby the speeds of the two crank shafts are again equalised.

Advantages of our present invention over that disclosed in the prior specification 335,932 are that:—

Induction machines which are cheaper and require no auxiliary exciters can be used.

No special apparatus is required for starting, as in the use of synchronous motors.

No trouble can arise through the motors falling out of step. If, for any reason, a momentary overload should take place on one crank shaft, thereby throwing it out of its proper phase relationship with the other shaft, the hunting controller immediately takes control and once more equalises the speeds.

Dated the third day of November, 1932.

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COMPLETE SPECIFICATION.

Improvements in Reciprocating Pumps.

We, G. & J. WEIR LIMITED, of Holm Foundry, Cathcart, Glasgow, a British Company, HAROLD HILLIER, of the same address, a British Subject, JAMES COLQUHOUN MACFARLANE and WILLIAM ALLAN MACFARLANE, Directors of the Macfarlane Engineering Company, Limited, of Netherlee Road, Cathcart, Glasgow, both British Subjects, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In the prior specifications 335,932, 336,810 and 337,205 there are described devices for obtaining a variable delivery from a reciprocating pump comprising a pair of co-acting displacers, such as plungers, working in a common chamber, or a plurality of pairs of co-acting displacers, each pair working in a common chamber, the volumetric discharge from which chamber or each of which chambers is dependent upon the relative timing of the displacers.

To obtain a small cyclic variation in discharge pressure, three or five pairs of co-acting displacers may be provided, but in its simplest form, such a pump comprises a pump chamber, admission and discharge valves for controlling the flow of fluid into and out of said chamber, two-crank shafts rotating at equal speeds, and a pair of co-acting plungers, preferably of equal displacement, driven by said crank-shafts and operating within said chamber to vary the net volumetric capacity of the chamber, variation in the volumetric discharge from which is effected by varying the phase relationship of the crank-shafts.

In specification 335,932 there is described an arrangement in which the two crankshafts are driven by synchronous motors, and the relative timing of the two crank-shafts is varied by partially rotating the stator of at least one of these motors so as to alter the position of the poles of said stator relatively to the poles of the stator of the other motor.

Our present invention, which may be regarded as an improvement on and simplification of that described in specification 335,932, makes use of motors having fixed stators, associated with means controlled by the delivery pressure (or volume) of the discharged fluid and adapted momentarily to bring about differential speeding of the rotors of said motors

whereby to change the relative timing of the crank-shafts driven by said motors.

For the purpose of driving the two shafts at equal speeds we may use A.C. induction motors of either the slip-ring or the squirrel-cage type, or, where a D.C. supply is available, we may use D.C. motors.

In practice we may exercise a choice of several means for initiating differential speeding of the rotors of said motors. Preferably said means is constituted by a hunting controller including two parts, one part controlled by the delivery pressure of the discharged fluid, so that a movement of said part, due to change in delivery pressure initiates differential speeding of the motors to vary the phase relationship of the two crankshafts, and the second part being responsive to the variation in the phase relation of the crank-shafts, and being moved to compensate for the movement of the first part to restore equality of the speeds of the motors when the desired relation between the pump output and the delivery pressure is attained. The hunting controller may be arranged to give any desired relation between delivery pressure and pump output from no output to maximum output.

In one embodiment of our invention including slip-ring induction motors the hunting controller may be arranged to insert or to cut out resistance in the rotor circuit of one or each motor.

A squirrel-cage motor with a relatively high resistance rotor may be used in conjunction with a slip-ring motor, in which the resistance is inserted or removed from the rotor circuit, thus increasing or reducing its slip relatively to that of the squirrel-cage motor, thereby causing differential speeding of the rotors until the required change in timing of the crankshafts is effected.

Or the crank-shafts may be driven by two induction motors, preferably of the squirrel-cage type, each coupled to a D.C. machine adapted to control the slip within the desired limits. The D.C. machines may be driven by belt, chain or other gear, but are preferably coupled direct to the A.C. motors. These D.C. machines have armature circuits coupled in opposition, so that with equal fields the same voltage is generated in each and no current flows. When, however, the hunting controller operates to insert resistance in one field and to remove resistance from the other field, one D.C. machine becomes a motor and the other D.C. machine becomes a generator, thus transferring power from one A.C. motor shaft to the other A.C. motor shaft. The effect is to decrease the speed of the rotor of the A.C. motor coupled to the generating D.C. machine and to increase the speed of the rotor of the A.C. motor coupled to the motoring D.C. machine, and thereby to alter the relative timing of the two crankshafts.

Where a D.C. supply is available, the shaft-driving motors may be D.C. machines, in which case the hunting controller is arranged to operate directly to insert resistance in the field circuit of one machine and remove it from the field circuit of the other, and vice versa.

The hunting controller consists, as aforesaid, of two parts, one part being a device, such as a piston or diaphragm, or the equivalent, such as a Bourdon tube, responsive to changes in the delivery pressure of the pump, and adapted to actuate a regulator which brings about the appropriate differential speeding of the driving rotors.

The second part of the hunting controller is influenced by the change of relative timing of the crank-shafts, and actuates the regulator until the delivery pressure and the pump output are in the desired relation. In one form, the second part of the hunting controller consists of a differential gear interconnecting the two crank-shafts and including two main bevel wheels rotated in opposite directions, one by each crank-shaft, and two intermediate bevel wheels each meshing with both said main bevel wheels and journalled in a casing operatively connected to the regulator. The intermediate bevel wheels rotate idly and the casing remains stationary so long as the speeds of the two crank-shafts are equal. When, however, differential speeding of the crank-shafts takes place, the casing makes a partial rotation, and, being operatively connected to the regulator, moves the regulator in the direction to restore equality of speeds of the crank-shafts.

The first part of the hunting controller may include the movable contact of a potentiometer, the position of which contact is determined by the device responsive to the feed delivery pressure, the arrangement being such that, when the delivery pressure and pump output are in the desired relation, the contact is in mid-position on the potentiometer, the speeds of the rotors of the two driving motors being then equal. A change in the delivery pressure of the pump causes the pressure-responsive device to move the contact away from said position in the direction to initiate differential speeding of the rotors and thus of the crank-shafts. Such differential speeding, however, causes the second part of the hunting controller to move the potentiometer proper in such wise as to compensate for the movement

of the contact, thereby bringing the mid-point of the potentiometer into register with the contact and discontinuing the differenial speeding of the rotors.

The potentiometer may be of circular form and revoluble about its centre, or it may be of the rectilinearly movable type.

Resilient contacts may be used in conjunction with means for reducing or eliminating sparking at the contacts.

The second part of the hunting controller may comprise electrical devices instead of gearing. For example, the electrical current set up in the circuit of the auxiliary machines may be utilised to operate a motor, solenoid, or other device, for the purpose of restoring the regulator to equilibrium position after the action of the first part of the hunting controller.

In the accompanying drawings which illustrate the invention Fig. 1 shows diagrammatically a variable delivery reciprocating pump driven by two induction motors coupled to D.C. machines, the plungers being represented as being in phase, corresponding to maximum delivery. Fig. 2 shows diagrammatically the same pump as in Fig. 1 but with the plungers represented as being in opposite phase, corresponding to minimum delivery. Fig. 3 shows a modified arrangement of the hunting controller. Fig. 4 shows a further modified arrangement of the hunting controller. Fig. 5 shows diagrammatically an arrangement incorporating a slip-ring motor having a variable rotor resistance, the plungers being shown in phase. Fig. 6 is a view similar to Fig. 5 but with the plungers shown out of phase. Fig. 7 shows a further modification hereinafter referred to.

For the sake of simplicity, the reciprocating pumps shown in Figs. 1, 2, 5 and 6 are represented as single-throw pumps, but it is to be understood that, in order to reduce cyclic variations in the discharge pressure, the pumps will preferably be constructed with three pairs of plungers, or five pairs of plungers, such arrangement giving a small cyclic variation in the discharge pressure.

Referring to Figs. 1 and 2 of the drawngs, 1 and 1*a* denote two co-acting plungers driven by separate crankshafts 5 and 5*a*, respectively, and adapted to operate in a common chamber 2 provided with a suction valve 3 and with a discharge valve 4. As shown in Fig. 1, the crankshafts 5 and 5*a* are in phase, so that the volumetric displacement is the maximum. The crank-shafts 5 and 5*a* are driven normally at equal speeds through gearing 7 and 7*a* by induction motors 6 and 6*a* which are preferably of the squirrel-cage type. Directly coupled to the motors 6 and 6*a* are two D.C. machines 8 and 8*a* the armature circuits of which are connected in opposition, so that with equal fields the same voltage is generated in each and no current flows. The delivery pressure in the pump discharge pipe 9 acts on one end of a piston 10 in opposition to a spring 11 acting on the other end of said piston 10. A damping device may be fitted in the pipe 9*a* connecting the pump discharge pipe 9 to the piston 10, so as to ensure that the piston 10 is subjected only to the mean delivery pressure in the pump discharge pipe 9 and is not affected by cyclic variations in the pump discharge pressure. A spindle 12 attached to the piston 10 is operatively connected to the sliding contact 13 of a potentiometer 14.

The crankshafts 5 and 5*a* drive bevel wheels 15 and 15*a*, shafting, and bevel wheels 16 and 16*a* of a differential gear. Meshing with the bevel wheels 16 and 16*a* are two intermediate bevel wheels 17 and 18 journalled in a casing 19 rotatable about the common axis of the bevel wheels 16 and 16*a* and presenting a cam 20 cooperating with a follower on a spindle 21 connected to the potentiometer 14. The potentiometer resistor is coupled in series with the fields 22 and 22*a* of the D.C. machines 8 and 8*a*, the brushes of which machines are coupled to form a circuit 23 electrically connected to the contact 13 of the potentiometer 14.

With the contact 13 in mid-position with respect to the resistor the voltage generated by the machine 8 is equal to the voltage generated by the machine 8*a* and no current flows in the circuit 23. If, however, the contact 13 is moved to unbalance the resistance, for example to insert additional resistance in the field 22, and to cut out resistance from the field 22*a*, the D.C. machine 8*a* becomes a generator while the D.C. machine 8 becomes a motor, thus transferring power from the shaft of the induction motor 6*a* to the shaft of the induction motor 6. The effect is to increase the speed of the rotor of the induction motor 6 and to reduce the speed of the rotor of the induction motor 6*a*, so that the crankshafts 5 and 5*a* are differentially speeded to bring about variation in the relative timing of said crankshafts.

When the crankshafts 5 and 5*a* are differentially speeded, the bevel wheel drive 15 and 15*a* causes the casing 19 partially to rotate the cam 20 and thereby displace the potentiometer 14 until the contact 13 is again at the mid-point of

the resistor, when the resistances in the fields 22 and 22a will again be equal. No current will then flow in the circuit 23, the D.C. machines 8 and 8a will generate equal voltages, and the rotors of the motors 6 and 6a will again rotate at equal speeds, the crankshafts 5 and 5a being now out of phase.

Fig. 2 shows the plungers in the opposite phase position corresponding to minimum pump delivery. It will be understood that, by varying the phase relation of the two crankshafts 5 and 5a between the position shown in Fig. 1 and the position shown in Fig. 2, any pump delivery between maximum capacity and minimum capacity can be obtained. The pressure in the pump delivery pipe 9 controls the position of the piston 10 which is the first part of the hunting controller, movement of the piston 10 being communicated to the potentiometer contact 13 which causes the requisite differential speeding of the rotors of the motors 6 and 6a to produce the required change in the phase relation of the crankshafts 5 and 5a. The change in the phase relation of the crankshafts 5 and 5a causes the second part of the hunting controller, comprising the parts 15 to 21, to displace the potentiometer 14 in the direction to restore the resistor to equilibrium position, so that the delivery pressure in the pipe 9 and the pump output are in the desired relation. For any given delivery pressure there is a corresponding phase relation of the crankshafts 5 and 5a and therefore a corresponding pump output. With the spring 11 arranged as shown in Figs. 1 and 2 the delivery pressure will fall continuously from minimum pump output corresponding to the opposite phase position shown in Fig. 2 to maximum output corresponding to the in phase position shown in Fig. 1, so that the pressure capacity characteristic of the pump will fall continuously from no load to full load.

As shown in Fig. 3, the arrangement is such that the delivery pressure of the pump will rise continuously from no load to full load and the pressure capacity characteristic of the pump will closely approximate to the resistance capacity characteristic of the delivery system, the power required to drive the pump being thereby reduced to the minimum for all capacities.

In this arrangement the second part of the hunting controller operates one end of a lever 13^1 carrying the contact 13, the other end of said lever being operated by the piston 10 through the spindle 12. The lever 13^1 is horizontal with the contact 13 at mid-position of the potentiometer when a given pump output corresponds to the predetermined delivery pressure for that output. If the contact 13 rises due to a fall in pressure, the output of the pump will be increased until the spindle 21 causes the contact to regain the mid position. Conversely, with rise in pressure the output of the pump is decreased.

Fig. 4 shows an alternative arrangement of the hunting controller to obtain a rising pressure capacity characteristic. The second part of the hunting controller determines the position of the spring base 21a in accordance with the relative timing of the crankshafts. For any given output of the pump the delivery pressure causes a corresponding compression of the spring 11. The contact 13 being normally in mid-position on the potentiometer 14, a fall in delivery pressure, due to the output being smaller than the demand, will raise the contact 13. At the same time as the pump output is increased, the base 21a is displaced in the direction to restore the contact 13 to mid-position, whereupon the pump continues to run at increased output. Oppositely directed movements of the contact and base are brought about by an increase in delivery pressure due to the output being greater than the demand.

While we have described a differential gear driven by the crankshafts as constituting the operating mechanism of the second part of the hunting controller, it will be understood that the second part of the hunting controller may be actuated by other mechanism responsive to change in the relative timing of the crankshafts.

The second part of the hunting controller may comprise electrical devices, as shown, for example, in Fig. 7, which is generally similar to Figs. 1 and 2, the rotor speeds of the driving motors 6 and 6a are equal when there is no flow of current through the circuit 23, whereas, if the piston 10 moves the contact 13 to insert additional resistance in the field 22 and to cut out resistance from the field 22a, the D.C. machine 8a becomes a generator and current flows through the circuit 23 from the machine 8a to the machine 8. A small motor 29 is arranged in the circuit 23 and is operated by the flow of current from the machine 8a to the machine 8, the rotation of the motor 29 being communicated to the spindle 21 through gearing 30 and 31 and the cam 20 to displace the potentiometer 14 until the contact 13 is again at the mid point of the resister, when the resistances in the fields 22 and 22a will again be equal. No current will then flow in the circuit 23, the small motor will stop, the D.C.

machines 8 and 8a will generate equal voltages, and the rotors of the motors 6 and 6a will again rotate at equal speeds. The small motor 29 is arranged to be reversible so that a flow of current from the machine 8 to the machine 8a will cause the motor 29 to rotate in the opposite direction. The flow of current in the circuit 23 may be used to energise a solenoid, instead of the motor 29, to cause the required movements of the spindle 21 for the purpose of restoring the potentiometer 14 to equilibrium position after a movement of the potentiometer 14 has been effected by the first part of the hunting controller.

Referring to Figs. 5 and 6, the crankshaft 5a is driven by a squirrel-cage motor 26 having a relatively high resistance rotor running at a substantially constant speed. The crankshaft 5 is driven by a slip-ring induction motor 25 the rotor circuit of which is provided with a variable resistor 27, so that by variation of the resistance in the rotor circuit, due to movement of the contacts 28, caused by a change in delivery pressure in the pipe 9 acting on the piston 10, the speed of the rotor of the motor 25 is increased or reduced relatively to the speed of the rotor of the motor 26 for the period of time necessary to change the relative timing of the crankshafts 5 and 5a to bring about the requisite change in pump output. Any movement of the piston 10, which is the first part of the hunting controller, varies the resistance and causes a variation in the relative timing of the two crankshafts by differentially speeding the rotors of the two motors 25 and 26, while the changing of the relative timing of the two crankshafts causes the second part of the hunting controller, comprising the parts 15 to 21, to restore the resistor to the position at which the speed of the rotor of the slip-ring motor 25 is equal to the speed of the rotor of the squirrel-cage motor 26 with the pump output modified as required by the delivery pressure.

The motor 26 may be of the slip-ring induction type with a variable rotor resistance arranged to increase the speed of the rotor of the motor 26 when the speed of the rotor of the motor 25 is being reduced and to decrease the speed of the rotor of the motor 26 when the speed of the rotor of the motor 25 is being increased.

While we have represented the pressure responsive device as a piston acting against a spring in all the forms shown and described, it will be understood that the pressure responsive device may be constituted by any suitable device, such as, for example, a Bourdon tube which responds to changes in pressure and the movement of which is transmitted, with or without magnification or diminution, as may be desired.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A reciprocating pump having, in combination, at least one pair of displacers driven by separate shafts, motors having fixed stators and rotors normally rotating at equal speeds for driving said shafts, and means controlled by the pressure of the discharged fluid and adapted momentarily to cause differential speeding of said rotors to vary the relative timing of said shafts.

2. A reciprocating pump, having, in combination, at least one pair of displacers driven by separate shafts, a substantially constant speed motor driving one of said shafts, a motor having a fixed stator and a variable speed rotor adapted normally to drive the other of said shafts at the same speed as the first mentioned shaft, and means controlled by the pressure of the discharged fluid for momentarily varying the speed of said rotor to vary the relative timing of said shafts.

3. A reciprocating pump as claimed in claim 1 or claim 2 in which the means for varying the relative timing of the shafts comprises a part controlled by the pressure of the discharged fluid, and a part controlled in synchronism with the variation of the relative timing of said shafts.

4. A reciprocating pump as claimed in claim 1 or claim 2 incorporating a differential gear including a member responsive to variation in the relative timing of the shafts, and means cooperative with said member for restoring equality of speeds of the shafts.

5. In a reciprocating pump, in combination, at least one pair of displacers driven by separate shafts, motors for rotating said shafts normally at equal speeds, D.C. machines coupled to said motors and having armature circuits connected in opposition, a potentiometer controlling the field circuits of said machines, means comprising a device responsive to the pressure of the discharged fluid and acting on said potentiometer to initiate differential speeding of said motors to vary the relative timing of said shafts, and mechanism responsive to change in the relative timing of said shafts and acting on said potentiometer in opposition to said device to restore

equality of speeds of said motors.

6. A reciprocating pump as claimed in claim 2 in which the second shaft is driven by a slip-ring induction motor with a rotor resistance which is varied to bring about differential speeding of the motors.

7. A reciprocating pump as claimed in claim 1 in which the shafts are driven by slip-ring induction motors the rotor resistances of which are varied to bring about differential speeding of the motors.

8. Reciprocating pumps constructed and arranged to operate as described with reference to the accompanying drawings.

Dated the twelfth day of October, 1933.

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SHEET 1

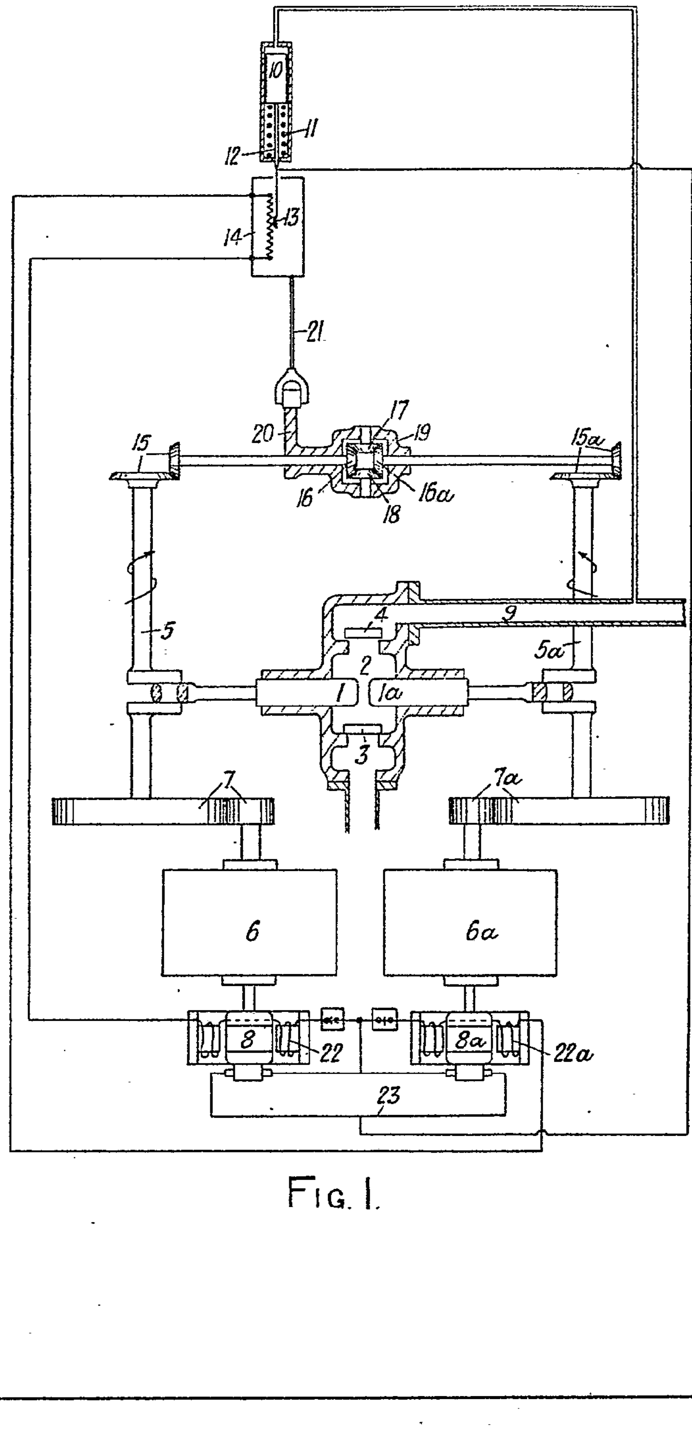

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FIG. 1.

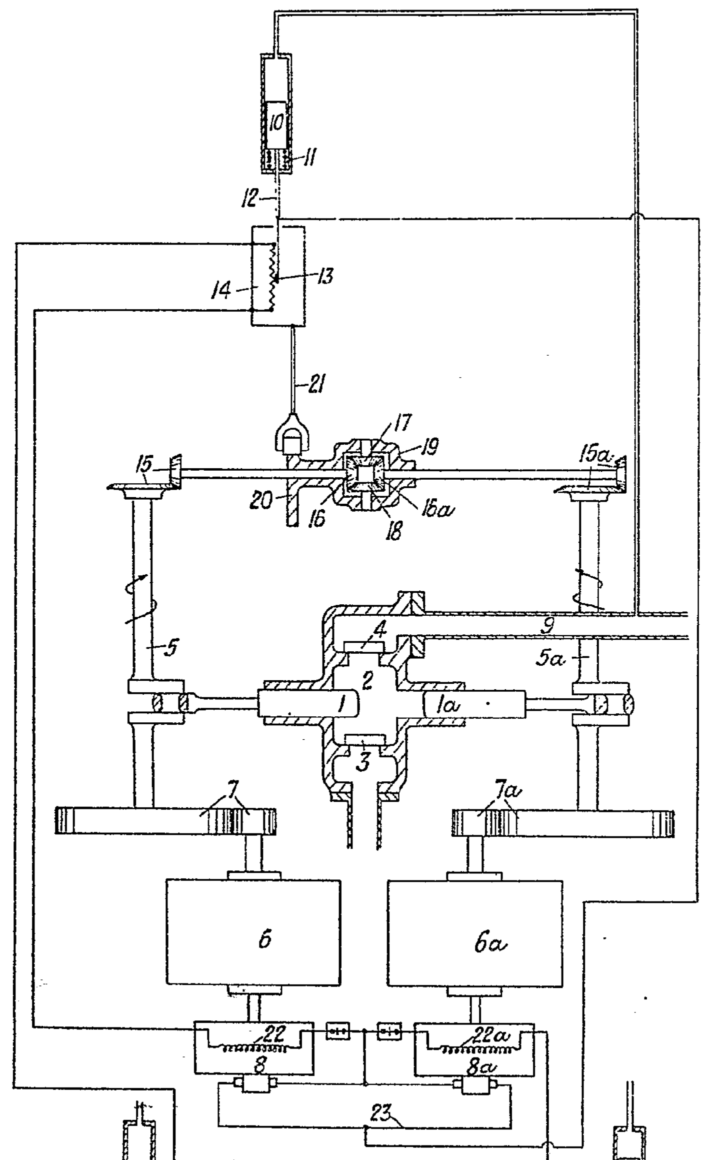

Fig. 2.

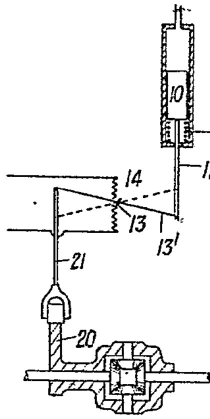

Fig. 3

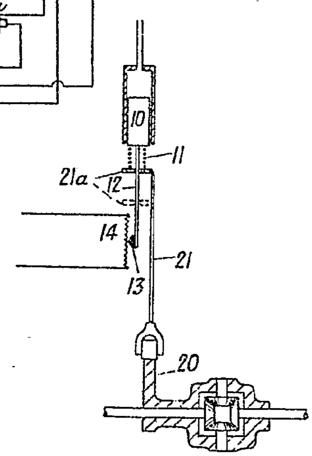

Fig. 4.

[This Drawing is a reproduction of the Original on a reduced scale.]

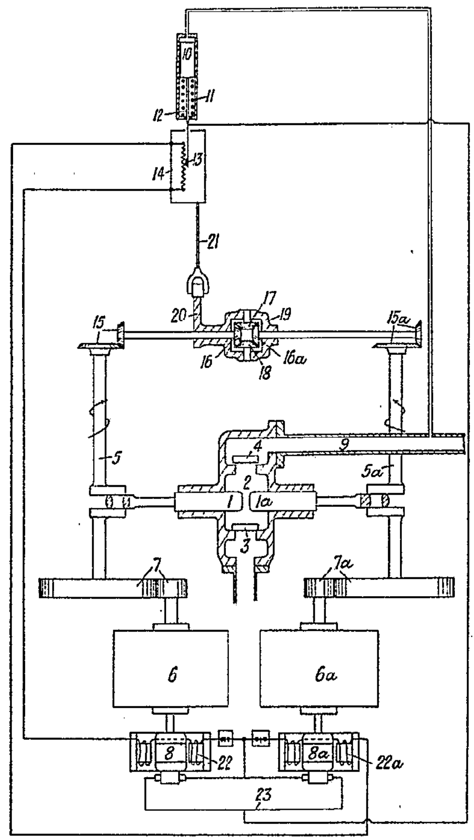

FIG. 1.

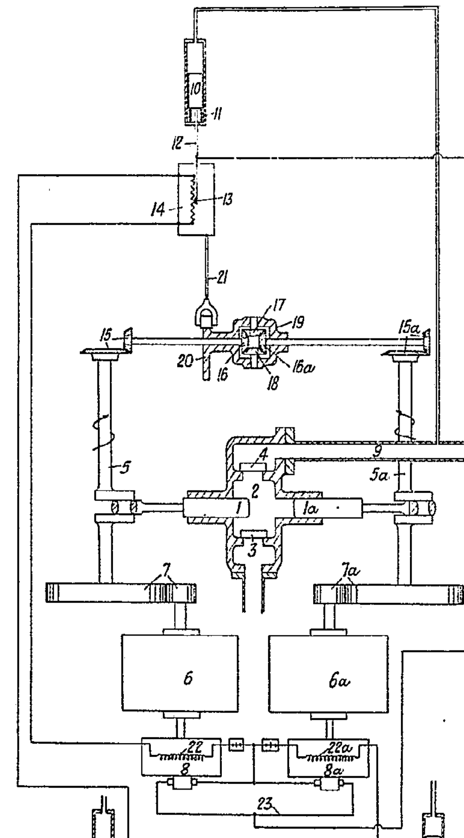

FIG. 2.

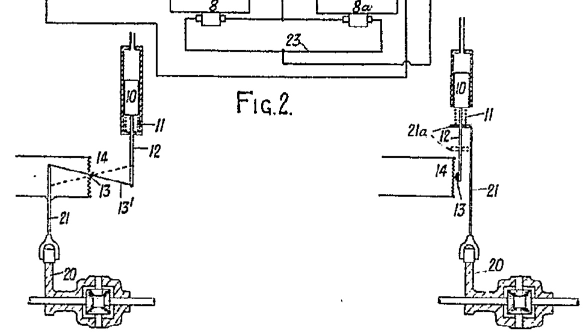

FIG. 3

FIG. 4.

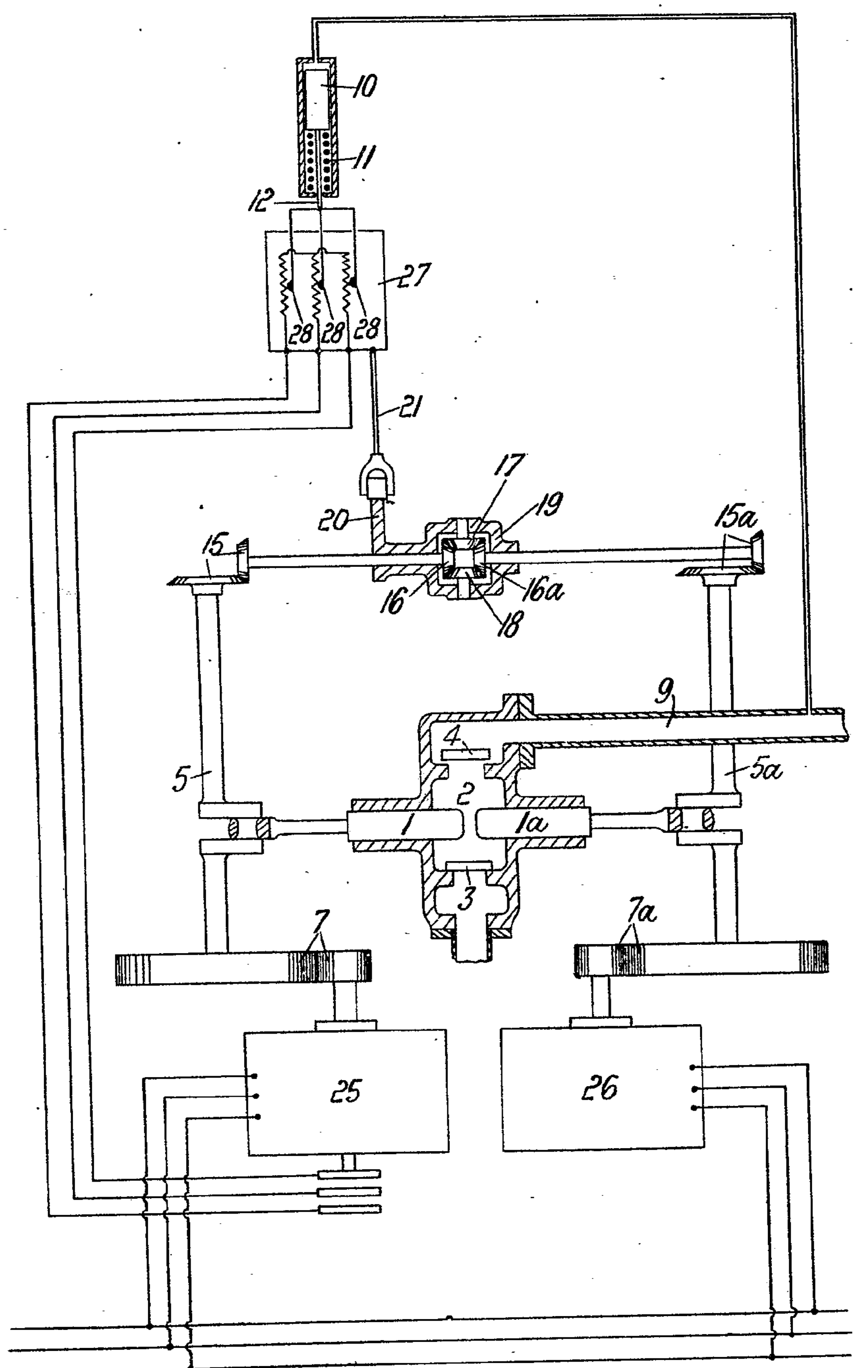
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FIG. 5.

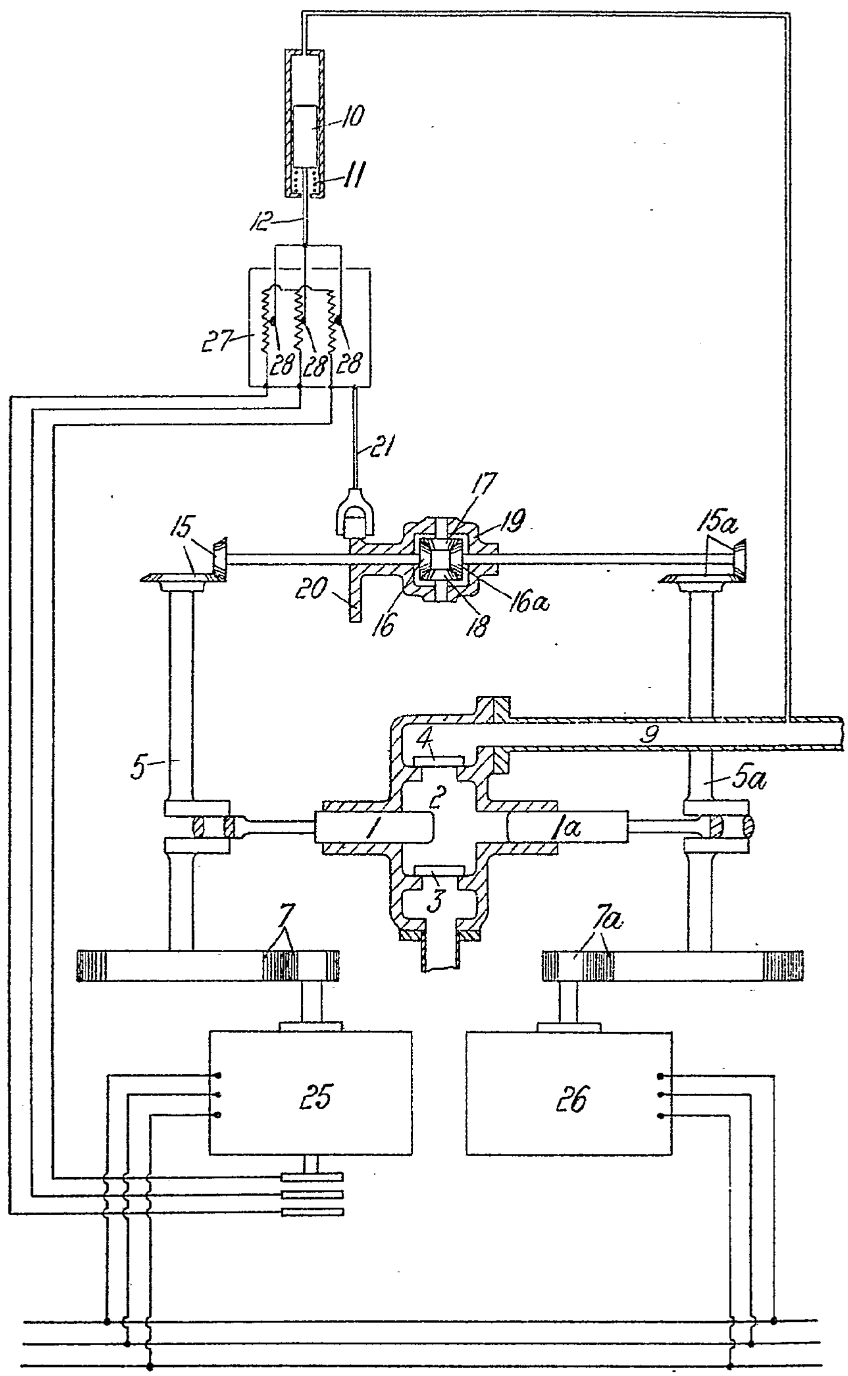
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FIG. 6.

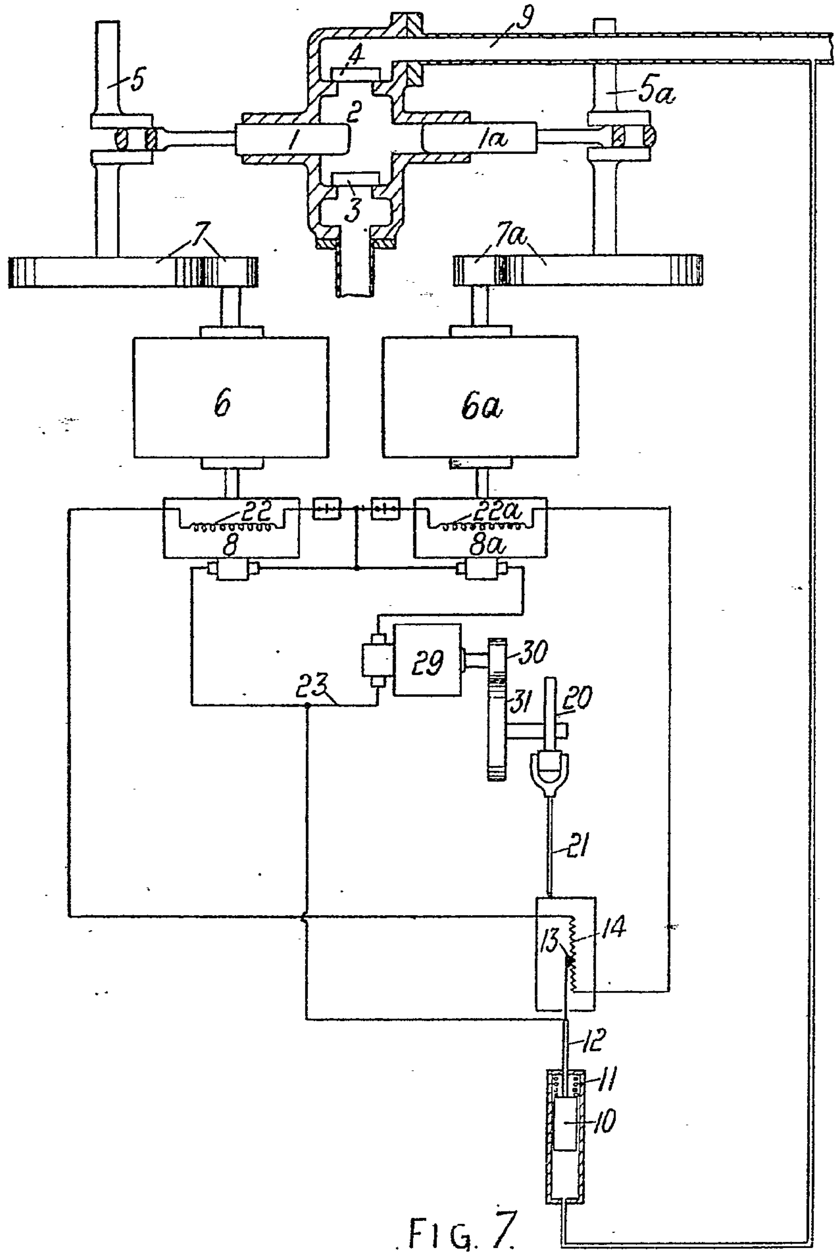

FIG. 7.

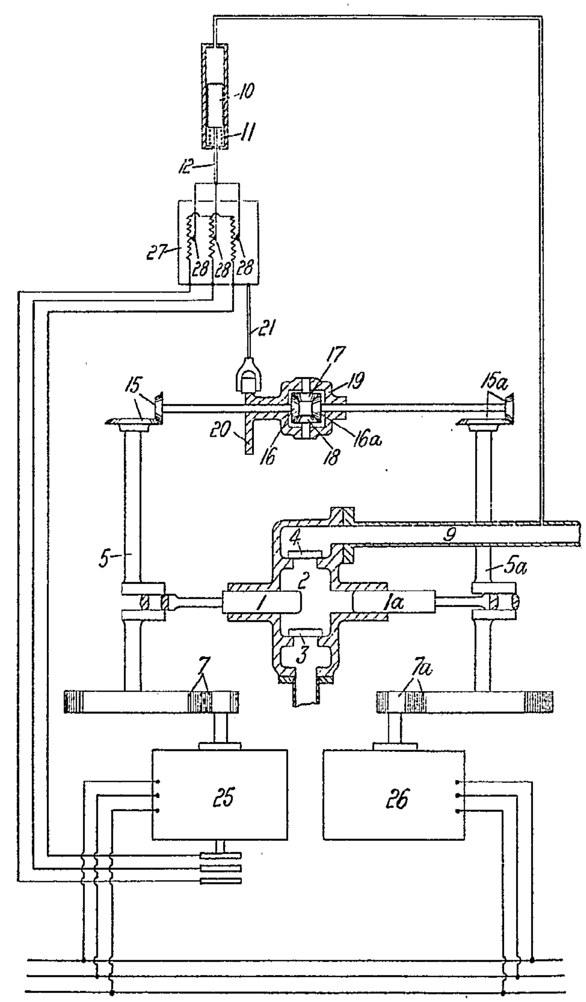

FIG 6.

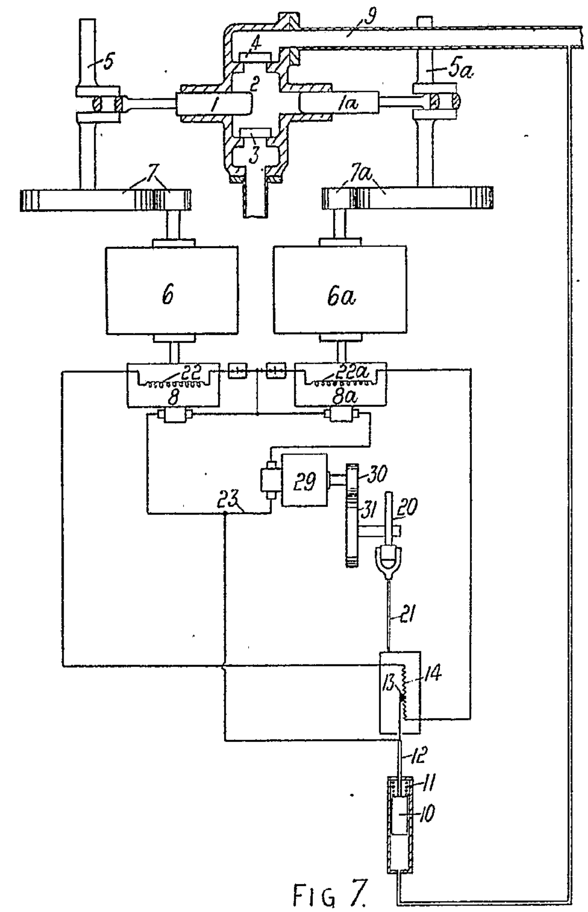

FIG 7.

[This Drawing is a reproduction of the Original on a reduced scale.]